

AMENDMENT UNDER 37 C.F.R. § 1.111
Application No. 10/617,822
Atty Docket No.: Q71182

AMENDMENTS TO THE SPECIFICATION

Please replace paragraph no. [0006], on page 2, with the following amended paragraph:

[0006] In recent years, the use of a magnetic monopole head, which has an excellent ability to write to a perpendicular recording film, is being studied with respect to needs to further raise the recording density of magnetic recording media. To use the head, it is being proposed to use a magnetic recording medium in which the efficiency of the magnetic flux transfer between the magnetic monopole head and the magnetic recording medium is improved by the provision of a backing layer constituted of what is called a softlysoft magnetic material between the perpendicular recording film constituting the recording layer and the substrate.

Please replace paragraph no. [0008], on page 2, with the following amended paragraph:

[0008] A perpendicular magnetic recording medium generally comprises a backing layer (softlysoft magnetic underlayer) provided on the substrate, an orientation control film that orients the axis of easy magnetization of the magnetic layer perpendicular to the substrate surface, a perpendicular magnetic recording film of Co alloy, and a protective film, in that order. Of these, it goes without saying to use low-noise magnetic materials for the perpendicular magnetic recording film in order to improve the recording and reproduction characteristics of the magnetic recording medium, but with respect also to the layer structure, the following are examples of a number of proposed improvement techniques.

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Please replace paragraph no. [0013], on page 4, with the following amended paragraph:

[0013] To achieve the above object the present invention provides a magnetic recording medium having a nonmagnetic substrate on which is provided at least a softlysoft magnetic under-film, an orientation control film that controls an orientation of a film directly above, a perpendicular magnetic recording film having an axis of easy magnetization oriented to be mainly perpendicular to the substrate, and a protective film, wherein the orientation control film has a material composition forming a C11_b structure.

Please replace paragraph no. [0022], on page 5, with the following amended paragraph:

[0022] The present invention further provides a method of manufacturing any one of the magnetic recording media, comprising carrying out, in order, at least a step of forming a softlysoft magnetic under-film on a nonmagnetic substrate, a step of forming an orientation control film that controls an orientation of a film directly above, a step of forming a perpendicular magnetic recording film having an axis of easy magnetization oriented to be mainly perpendicular to the substrate, and a step of forming a protective film.

Please replace paragraph no. [0030], on page 6, with the following amended paragraph:

[0030] Figure 1 shows an example of an aspect of a first embodiment of the magnetic recording medium of the present invention. The magnetic recording medium shown in this figure comprises a softlysoft magnetic under-film 2, an orientation control film 3, an

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intermediate film 4, a perpendicular magnetic recording film 5, a protective film 6 and a lubricant film 7 deposited in that order on a nonmagnetic substrate 1. The configuration is described below in order from the nonmagnetic substrate 1 side.

Please replace paragraph no. [0034], on page 7, with the following amended paragraph:

[0034] The ~~softly~~soft magnetic underlayer 2 is provided to more securely fix the magnetization direction of the perpendicular magnetic recording film 5 on which information is recorded perpendicular to the nonmagnetic substrate 1 and to increase the perpendicular component, relative to the substrate, of the magnetic flux generated by the magnetic head. It is desirable for this effect to be particularly pronounced when a magnetic monopole head for perpendicular recording is used as the recording and reproduction magnetic head.

Please replace paragraph no. [0035], on page 7, with the following amended paragraph:

[0035] As the ~~softly~~soft magnetic material used to form the ~~softly~~soft magnetic under-film 2, there can be used material containing Fe, Ni and Co. Specific materials include FeCo-based alloy (FeCo, FeCoV, etc.), FeNi-based alloy (FeNi, FeNiMo, FeNiCr, FeNiSi, etc.), FeAl-based alloy (FeAl, FeAlSi, FeAlSiCr, FeAlSiTiRu, FeAlO, etc.), FeCr-based alloy (FeCr, FeCrTi, FeCrCu, etc.), FeTa-based alloy (FeTa, FeTaC, FeTa_N, etc.), FeMg-based alloy (FeMgO, etc.), FeZr-based alloy (FeZr_N, etc.), FeC-based alloy, FeN-based alloy, FeSi-based alloy, FeP-based alloy, FeNb-based alloy, FeHf-based alloy and FeB-based alloy. A material having a fine crystal structure, such as FeAlO, FeMgO, FeTa_N and FeZr_N, containing 60 at% or

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more Fe can be used, or a material having a granular structure in which fine crystal grains are dispersed in the matrix. Materials that can be used for the softlysoft magnetic under-film 2, in addition to the above, include Co alloy containing at least 80 at% Co and at least one selected from Zr, Nb, Ta, Cr, Mo and the like. CoZr, CoZrNb, CoZrTa, CoZrCr, CoZrMo and other such alloys are particularly suitable.

Please replace paragraph no. [0036], on page 8, with the following amended paragraph:

[0036] It is desirable for the coercive force H_c of the softlysoft magnetic under-film 2 to be not more than 100 (Oe) (more preferably not more than 20 (Oe)). It is undesirable for the coercive force H_c to exceed the above range, since the softlysoft magnetic property will then be not enough and the reproduction waveform will be distorted from a so-called square wave.

Please replace paragraph no. [0037], on page 8, with the following amended paragraph:

[0037] The product $B_s \cdot t$ (T·nm) of the saturation magnetic flux density B_s (T) of the softlysoft magnetic under-film 2 and the film thickness t (nm) of the softlysoft magnetic under-film 2 should be not less than 40 (T·nm) (more preferably not less than 60 (T·nm)). It is undesirable for the $B_s \cdot t$ to be less than that, as the reproduction waveform will then be distorted and the OW characteristics degraded. The thickness of the film layer can be obtained by observation with a TEM (transmission electron microscope).

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Please replace paragraph no. [0038], on page 8, with the following amended paragraph:

[0038] It is also desirable for the material of the surface of the softlysoft magnetic under-film 2 (the surface on the orientation control film 3 side) to be partially or wholly oxidized. That is, it is desirable for the material of the surface of the softlysoft magnetic under-film 2 (the surface on the orientation control film 3 side) and the vicinity thereof to be partially oxidized, or for oxides of the material to be formed and disposed. Doing this enables magnetic fluctuation of the surface of the softlysoft magnetic under-film 2 to be restrained, reducing noise caused by such magnetic fluctuation, and thereby improving the recording and reproduction characteristics of the magnetic recording medium. Also, recording and reproduction characteristics can be improved by finely granulizing the crystal grains of the orientation control film 3 formed on the softlysoft magnetic under-film 2.

Please replace paragraph no. [0039], on page 8, with the following amended paragraph:

[0039] The surface of the softlysoft magnetic under-film 2 (the surface on the orientation control film 3 side) and the vicinity thereof can readily be oxidized, partially or wholly, by, for example, a method in which the softlysoft magnetic under-film 2 is formed and then exposed to an atmosphere containing oxygen, or a method in which oxygen is introduced during formation of near-surface portions of the softlysoft magnetic under-film 2. Specifically, in the case of the method in which the surface of the softlysoft magnetic under-film 2 is exposed to oxygen, it can be maintained from 0.3 to 20 seconds in an oxygen atmosphere or an

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atmosphere in which oxygen is diluted with argon or nitrogen. It can also be exposed to the air. Particularly when oxygen is diluted with argon or nitrogen, it is easier to adjust the degree of oxidation of the surface of the softlysoft magnetic under-film 2, enabling stable fabrication. Also, in the case of the method in which oxygen is introduced into the gas used to form the film of the softlysoft magnetic under-film 2, if sputtering, for example, is used as the film growth method, it is only necessary to introduce the oxygen into the process gas for just part of the film growth time. In the case of argon as the process gas, for example, oxygen can be mixed at a volumetric ratio of 0.05% to 50% (preferably 0.1 to 20%).

Please replace paragraph no. [0043], on page 10, with the following amended paragraph:

[0043] Further, the orientation control film 3 should have a thickness of not less than 0.5 nm and not more than 20 nm (more preferably, 1 to 12 nm). When the thickness of the orientation control film 3 is within this range, the perpendicular orientation of the perpendicular magnetic recording film 5 becomes particularly high, and the distance between the magnetic head and the softlysoft magnetic under-film 2 during recording can be made small, making it possible to enhance the recording and reproduction characteristics without reducing the resolution of the reproduction signal. If the thickness is less than this range, the perpendicular orientation in the perpendicular magnetic recording film 5 is reduced, degrading the recording and reproduction characteristics and the resistance to thermal fluctuation. If this thickness range is exceeded, the perpendicular orientation of the perpendicular magnetic recording film 5 is reduced, degrading the recording and reproduction characteristics and the resistance to thermal

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fluctuation. Moreover, the distance between the magnetic head and the ~~softly~~soft magnetic under-film 2 during recording is increased, which is not desirable since the reproduction signal resolution and reproduction output is lowered.

Please replace paragraph no. [0047], on page 11, with the following amended paragraph:

[0047] As shown in the illustrated example, an intermediate film 4 can be provided between the orientation control film 3 and the perpendicular magnetic recording film 5 in order to improve the recording and reproduction characteristics. For this intermediate film 4, it is desirable to use a material having an hcp structure, with CoCr alloy, CoCrY1 alloy or CoY1 alloy (Y1: one, two or more selected from Pt, Ta, Zr, Ru, Nb, Cu, Re, Ni, Mn, Ge, Si, O, N and B) being particularly suitable. The intermediate film 4 should preferably contain 30 to 70 at% Co. The intermediate film 4 should preferably be not more than 30 nm thick (more preferably, not more than 20 nm) to prevent the recording and reproduction characteristics being deteriorated by coarsening of the magnetic particles in the perpendicular magnetic recording film 5, and to prevent the recording resolution being reduced by an increase in the distance between the magnetic head and the ~~softly~~soft magnetic under-film 2. Thus providing the intermediate film 4 enables the perpendicular orientation of the perpendicular magnetic recording film 5 to be increased, raising the coercive force of the perpendicular magnetic recording film 5 and further improving the recording and reproduction characteristics and the resistance to thermal fluctuation.

Please replace paragraph no. [0061], on page 15, with the following amended paragraph:

[0061] Figure 2 shows an example of an aspect of a second embodiment of the magnetic recording medium of the present invention, in which a permanent magnetic film 8 with mainly in-plane oriented magnetic anisotropy is provided between the nonmagnetic substrate 1 and the ~~softly~~soft magnetic under-film 2 of the first embodiment.

Please replace paragraph no. [0062], on page 15, with the following amended paragraph:

[0062] The permanent magnetic film 8 can be formed of CoSm alloy or CoCrPtY2 alloy (Y2: one, two or more selected from Pt, Ta, Zr, Nb, Cu, Re, Ni, Mn, Ge, Si, O, N and B) being suitable. It is desirable for the coercive force Hc of the permanent magnetic film 8 to be not less than 500 (Oe) (more preferably not less than 1000 (Oe)). It is also desirable for the permanent magnetic film 8 to have a thickness that is not more than 150 nm (more preferably not more than 70 nm). It is undesirable for the thickness to exceed 150 nm, since it would increase the surface roughness Ra of the orientation control film 3. It is also desirable for the permanent magnetic film 8 to be composed to be exchange-coupled to the ~~softly~~soft magnetic under-film 2, with magnetization oriented in the radial direction of the substrate.

Please replace paragraph no. [0063], on page 15, with the following amended paragraph:

[0063] Providing the permanent magnetic film 8 enables the formation of giant magnetic domains in the ~~softly~~soft magnetic under-film 2 to be more effectively controlled,

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preventing noise spikes from the magnetic walls and adequately lowering the error rate during recording and reproduction.

Please replace paragraph no. [0065], on page 16, with the following amended paragraph:

[0065] Next, an example of a method of manufacturing the magnetic recording medium according to the first (and second) embodiments will be described. First, the softlysoft magnetic under-film 2 is formed on the nonmagnetic substrate 1 by a method, such as sputtering. Then, if required, the surface of the softlysoft magnetic under-film 2 and the vicinity thereof are partially or wholly oxidized. Next, a method, such as sputtering, is used to form the orientation control film 3, intermediate film 4 and perpendicular magnetic recording film 5. Then, the protective film 6 is formed by a method, such as the CVD method, ion-beam method or sputtering method. Then, the lubricant film 7 is formed by the dipping method, spin-coating method or the like. When manufacturing the magnetic recording medium of the second embodiment, the step of forming the permanent magnetic film 8 between the nonmagnetic substrate 1 and the softlysoft magnetic under-film 2 can be included. Below, each process is explained.

Please replace paragraph no. [0066], on page 16, with the following amended paragraph:

[0066] If required, the nonmagnetic substrate 1 is washed and the nonmagnetic substrate 1 is placed in the chamber of the film formation apparatus. Also, if required, a heater, for example, is used to heat the nonmagnetic substrate 1 to a temperature of 100 to 400°C. Then,

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the softlysoft magnetic under-film 2, orientation control film 3, intermediate film 4 and perpendicular magnetic recording film 5 are formed on the nonmagnetic substrate 1 by DC or RF magnetron sputtering using a sputter target of a material having the same composition as the material of each layer. The sputtering conditions used to form the films are set as follows, for example. The chamber used for the formation is evacuated to a vacuum of 10^{-5} to 10^{-7} Pa. The nonmagnetic substrate 1 is placed in the chamber and Ar gas, for example, as the sputter gas, is introduced and a discharge used to perform sputter film formation. The power supplied at this time is 0.05 to 5 kW, and the discharge time and supplied power are regulated to obtain the desired film thickness. Specifically, a film thickness of 50 to 400 nm is desirable.

Please replace paragraph no. [0067], on page 17, with the following amended paragraph:

[0067] In forming the softlysoft magnetic under-film 2, it is desirable to use sputter targets (fused alloy targets or sintered alloy targets) made of the types of magnetic material described above, to facilitate formation of the softlysoft magnetic under-film.

Please replace paragraph no. [0068], on page 17, with the following amended paragraph:

[0068] After forming the softlysoft magnetic under-film 2, it is desirable to carry out the aforementioned process of partially or wholly oxidizing the surface thereof (on the orientation control film 3 side) by, for example, using a method in which, after the softlysoft magnetic under-film 2 is formed, it is exposed to an oxygen-containing atmosphere, or a method

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in which oxygen is introduced into the process during growth of near-surface portions of the softlysoft magnetic under-film 2.

Please replace paragraph no. [0069], on page 17, with the following amended paragraph:

[0069] After forming the softlysoft magnetic under-film 2, the orientation control film 3 is formed to a film thickness of 1 to 20 nm (more preferably 1 to 10 nm) by regulating the discharge time and supplied power.

Please replace paragraph no. [0080], on page 19, with the following amended paragraph:

[0080] A washed glass substrate (manufactured by Ohara Inc., Japan, with an outside diameter of 2.5 inches) was placed in the film formation chamber of the DC magnetron sputter apparatus (C-3010 manufactured by Anelva Corp., Japan). After the film formation chamber was evacuated until a vacuum of 1×10^{-5} Pa was achieved, using an 89Co-4Zr-7Nb (Co content 89 at%, Zr content 4 at%, Nb content 7 at%) target, a 160-nm softlysoft magnetic under-film 2 was formed on the glass substrate by the sputtering method. Using a vibrating sample magnetometer (VSM), the product $B_s \cdot t$ (T·nm) of the saturation magnetic flux density B_s (T) of the film and the film thickness t (nm) was confirmed to be 200 (T·nm). Next, the substrate was heated to 240°C and a 33Cu-67Hf target was used to form an 8-nm orientation control film on the softlysoft magnetic under-film. The saturation magnetization M_s of the film was confirmed to be 100 (emu/cc). A 65Co-30Cr-5B (Co content 65 at%, Cr content 30 at%, B content 5 at%) target was used to form a 10-nm intermediate film 4, and a 64Co-17Cr-17Pt-2B (Co content 64

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(Co content 64 at%, Cr content 17 at%, Pt content 17 at%, B content 2 at%) target was then used to form a 20-nm perpendicular magnetic recording film. For the above sputtering process, argon was used as the film growth process gas, and the film was formed at a pressure of 0.6 Pa. Next, the CVD method was used to form a 5-nm protective film 6. Next, the dipping method was used to form a lubricant film of perfluoropolyether, to thereby obtain a magnetic recording medium. The contents thereof are shown in Table 1.

Please replace Table 1, on page 21, with the following amended Table:

TABLE 1

	Soft Magnetic Under-film		Orientation Control Film		Intermediate Film		Perpendicular Magnetic Recording Film		Recording/Reproduction Characteristics				
	Composition	Bs x t (T nm)	Composition (at%)	Thickness (nm)	Composition (at%)	Thickness (nm)	Composition (at%)	Thickness (nm)		(Error rate) (10 ⁴)	Hc (Oe)	Mr/Ms	-Hn (Oe)
Example 1	CoZrNb	200	33Cu-67Hf	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.8		4255	1.00	500
Comp. Example 1	CoZrNb	200	60Ru-40Co	15	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-4.1		4250	0.77	100
Comp. Example 2	CoZrNb	200	Ti	20	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-2.1		3590	1.00	400
Comp. Example 3	CoZrNb	200	C	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-3.2		3760	0.88	100

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Please replace Table 2, on page 23, with the following amended Table:

TABLE 2

	Soft Magnetic Under-film		Orientation Control Film		Intermediate Film		Perpendicular Magnetic Recording Film		Recording/Reproduction Characteristics (Error rate) (10 ⁻³)
	Composition	Bs x t (T nm)	Composition (at%)	Thickness (nm)	Composition (at%)	Thickness (nm)	Composition (at%)	Thickness (nm)	
Example 1	CoZrNb	200	33Cu-67Hf	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.8
Example 2	CoZrNb	200	33Cu-67Ti	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.6
Example 3	CoZrNb	200	33Cu-67Zr	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.4
Example 4	CoZrNb	200	67Ge-33W	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.1
Example 5	CoZrNb	200	67Ge-33Mo	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.1
Example 6	CoZrNb	200	67Si-33Mo	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.2
Example 7	CoZrNb	200	67Si-33W	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.3
Example 8	CoZrNb	200	65Si-35Re	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.3
Example 9	CoZrNb	200	33Zn-67Hf	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.8
Example 10	CoZrNb	200	33Zn-67Ti	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.6
Example 11	CoZrNb	200	67Ni-33Ta	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.9

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Please replace paragraph no. [0087], on page 24, with the following amended paragraph:

[0087] Example 1 was used as a basis for fabricating magnetic recording media of Examples 12 to 16, except for the thickness of the orientation control film as shown in Table 3. For the sake of comparison, the orientation control films were given the same composition. Also, the ~~softly~~soft magnetic under-film, intermediate film and perpendicular magnetic recording film were given the same composition and thickness.

Please replace Table 3, on page 25, with the following amended Table:

TABLE 3

	Soft/Semi Magnetic Under-film		Orientation Control Film		Intermediate Film		Perpendicular Magnetic Recording Film		Recording/Reproduction Characteristics
	Composition	Bs x t (T nm)	Composition (at%)	Thickness (nm)	Composition (at%)	Thickness (nm)	Composition (at%)	Thickness (nm)	
Example 1	CoZrNb	200	33Cu-67Hf	5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.8
Example 12	CoZrNb	200	33Cu-67Hf	0.6	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.2
Example 13	CoZrNb	200	33Cu-67Hf	1.5	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.4
Example 14	CoZrNb	200	33Cu-67Hf	11	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.7
Example 15	CoZrNb	200	33Cu-67Hf	18	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.5
Example 16	CoZrNb	200	33Cu-67Hf	30	65Co-30Cr-5B	10	64Co-17Cr-17Pt-2B	20	-5.0

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Please replace paragraph no. [0090], on page 26, with the following amended paragraph:

[0090] As described in the foregoing, the magnetic recording medium of the present invention comprises, on a nonmagnetic substrate, at least a ~~softly~~soft magnetic under-film, an orientation control film for controlling orientation of the film above, a perpendicular magnetic recording film having an axis of easy magnetization oriented mainly perpendicular to the substrate and a protective film, in which the orientation control film is composed of a material having a C11_b structure, enabling the recording and reproduction characteristics to be improved.